Docket #: Whitwo.H-01

APPLICATION

Of

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And

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For

UNITED STATES LETTERS PATENT

On

Internal Screw Positive Rod Displacement Metering Pump

Sheets of Drawings: Two

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TITLE: Internal Screw Positive Rod Displacement Metering Pump

BACKGROUND OF THE INVENTION

INCORPORATION BY REFERENCE: Applicant(s) hereby incorporate herein by reference, any and all U. S. patents, U.S. patent applications, and other documents and printed matter cited or referred to in this application.

FIELD OF THE INVENTION:

This invention relates generally to metering pump systems and more particularly to a new pump design having relatively short length and high speed switching for continuous fluid flow.

DESCRIPTION OF RELATED ART:

The following art defines the present state of this field:

Nichols et al., U.S. 4,089,624 describes a pumping system for dispensing controlled and variable amounts of fluids in predetermined quantities including a pump piston, which moves axially in a pump chamber. The piston is reciprocated by a drive lead nut cooperating with a non-rotatable lead screw attached to the piston. The piston is sealed to the pump chamber by a seal element whose distance from the lead nut is fixed regardless of the position of the piston, thus protecting the seal. The rotatably driven lead nut includes a hollow driven shaft, containing lubricant, so that the lead screw is lubricated as it travels into the shaft of the lead nut. The motor for the system is a pulse operated reversible stepping motor enabling accurate output from the pump, for example, between .01 ml/min to 9.99 ml/min as controlled by the stepping motor. One motor may drive two pumps for a

continuous controlled pumping system. If desired a flush mechanism may be used to rinse the piston of any pumped material which adheres to the surface.

Hutchins et al., U.S. 4,245,963 describes a pump for precise, smooth delivery of liquid, particularly in liquid chromatography systems, featuring two liquid displacement elements mounted for reciprocating movement in chambers connected in series with two check valves, one displacement element serving to accumulate some of the liquid delivered by the first element and to deliver the accumulated liquid while the first element is refilling.

Patterson et al., U.S. 4,352,636 describes a pump for producing a substantially smooth and continuous outflow of liquid at relatively high pressure having two piston assemblies flow connected in series. The first piston assembly includes a pressure piston having a long suction stroke and a relatively short and abrupt expulsion stroke. A valve at the inlet of the pressurization piston allows flow to enter (but not exit), and a valve at the outlet of the pressurization piston allows flow to exit (but not enter). The second piston assembly includes a damper piston which functions as a mechanically driven damper to smooth the outflow from the pressure piston. This smoothing is accomplished by storing of the liquid displaced by the expulsion stroke of the pressure piston and then delivering the stored pressurized liquid to the pump outlet during the suction stroke of the pressure piston. The drive for the pistons is constructed to produce an increased outflow of pressurized liquid for a short interval at the beginning of the expulsion stroke of the pressure piston to compensate for compressibility of the liquid at high pressure. At low pressure, the stepper motor drive is slowed down in response to the sensing of the increase of the outflow during this short interval to maintain the outflow smooth and continuous during this part of the cycle of operation.

Strohmeier et al., U.S. 4,883,409 describes a pumping apparatus for delivering liquid at a high pressure, in particular for use in liquid chromatography, comprising two pistons which reciprocate in pump chambers, respectively. The output of the first pump chamber is

connected via a valve to the input of the second pump chamber. The pistons are driven by linear drives, e.g., ball-screw spindles. The stroke volume displaced by the piston is freely adjustable by corresponding control of the angle by which the shaft of the drive motor is rotated during a stroke cycle. The control circuitry is operative to reduce the stroke volume when the flow rate, which can be selected by user at the user interface is reduced, thus leading to reduced pulsations in the outflow of the pumping apparatus. The pumping apparatus can also be used for generating solvent gradients when a mixing valve connected to different solvent containers is coupled to the input of the pumping apparatus.

Snodgrass et al., U.S. 5,516,429 describes a fluid dispensing system which has first diaphragm pump means, a filter connected to receive the discharge of said first pump, and accumulator/second diaphragm pump means connected to receive the discharge of said filter. Hydraulic fluids pumped by cylinder/piston/stepper assemblies independently actuate each of the diaphragm pumps, providing accurate, controllable and repeatable dispense of the subject fluid.

Muratsubaki et al., U.S. 6,068,448 describes a high pressure hydraulic pump apparatus constituting a two-stage pressurizing hydraulic booster combining a pair of plunger pumps. The first and second pumps are driven into a push-pull synchronous operation at the equal stroke with each other. The per-stroke displacement of the first pump is greater than that of the second pump. The first pump draws by self-suction the liquid from a reservoir while the second pump is on the pressurizing and delivery stroke. When the first pump is on the delivery stroke, the liquid pressurized to a certain intermediate pressure by the first pump is sucked into the second pump. During the next reverse stroke the second pump further pressurizes and discharges the liquid while the first pump effects the suction stroke. At the final pressurization by the second pump, the driving stroke length of the pump is controlled to a limited value, which provides a minimum delivery flow required for the interior of a load vessel to attain a target pressure in accordance with the compressibility of the liquid and the detection of a load pressure.

Ganzel, U.S. 6,079,797 describes a ball screw pump assembly including a pump body having an axial bore defining a travel chamber and a pressure chamber. An input port and an output port are formed in the pressure chamber. A ball screw is provided in the travel chamber. A piston is connected to the ball screw and slidably extends into the pressure chamber as the ball screw is rotated. The piston divides the pressure chamber into an input chamber having a maximum volume and an output chamber having a maximum volume which is less than the maximum of the input chamber. The ball screw pump assembly can be used in a vehicular braking system.

Eden et al., U.S. 6,510,780 describes a reversibly actuatable fluid hydraulic pump for use in a hydraulically driven elevator. The pump comprises a cylinder and a piston linearly actuatable within the cylinder by a ball screw race disposed over a spindle and connected to the piston. The shaft of the piston is hollow to receive the spindle as the piston is drawn along by virtue of the motion of the race along the spindle, and seals are provided at the free end of the piston which sealingly engage against the walls of the cylinder, and on the cylinder which sealingly engage with the shaft of the piston. A further feature of the invention is the provision of a compressible gas between the end of the cylinder and the end of the piston so that the expansion thereof reduces the work required to move the piston out of the cylinder, whereas when the system is relaxing, the compressible gas provides extra resistance and thus a smoother motion.

Britton Price Limited, WO 00/32932 describes a reversibly actuatable fluid hydraulic pump for use in a hydraulically driven elevator. The pump comprises a cylinder and a piston linearly actuatable within the cylinder by means of a ball screw race disposed over a spindle and connected to the piston. The shaft of the piston is hollow to receive the spindle as the piston is drawn along by virtue of the motion of the race along said spindle, and seals are provided at the free end of the piston which sealingly engage against the walls of the cylinder, and on the cylinder which sealingly engage with the shaft of the piston. A further

feature of the invention is the provision of a compressible gas between the end of the cylinder and the end of the piston so that the expansion thereof reduces the work required to move the piston out of the cylinder, whereas when the system is relaxing, the compressible gas provides extra resistance and thus a smoother motion.

ISCO, Inc., WO 02/068954 describes a plurality of pumps each having a corresponding one of a plurality of pistons and a corresponding one of a plurality of cylinders are driven by one motor to draw and pump solvent simultaneously into corresponding columns. To form a gradient, the pumps are connected to two-way valves that are connected alternately to a first solvent and a second solvent, whereby the time said valve is in a first position controls the amount of solvent drawn from the first reservoir into said pumps and the amount of time in said second position controls the amount of said second solvent drawn from the second reservoir into said pumps and the solvent is mixed in the pumping systems. The detectors are photodiodes mounted to light guides in the flow cells that generate signals related to light absorbance and communicate with a controller, whereby the controller receives signals indicating solute between the light guides and causes collection of solute. An over-pressure system compensates for pressure over a predetermined level.

The prior art teaches a controlled pumping system, a liquid pump for chromatography systems, a dual piston pump, a liquid high pressure pump, a fluid dispensing pump, a pressure hydraulic pump having synchronously driven reciprocating pistons, a dual action ball screw pump, a ball screw driven pump, and a liquid chromatographic method and system, but does not teach a metering pump that is highly compact by enabling its drive screw to penetrate its displacement rod. The present invention fulfills this need and provides further related advantages as described in the following summary.

SUMMARY OF THE INVENTION

The present invention teaches certain benefits in construction and use which give rise to the objectives described below.

A metering apparatus includes at least one pair of closed cylindrical housings each housing a fluid exchange port. A metering screw penetrates each housing longitudinally and rotates, first in clockwise, the then in counter-clockwise senses during alternate cycles of the method of the invention. Hollow rods are engaged with the screws so that the screws penetrate the rods and move the rods along the screws longitudinally within the housings by screw rotation. With the rods translating in a first direction a fluid is drawn into the housings alternately through the port, while with the rods translating in the opposing direction, the fluid is expelled from the same port. Plural sets of the pairs of closed housings are used with dual channel fluid switches to move the fluid into one of each of the pairs of housing on a first half of an operating cycle, and to draw the fluid from the one of the pairs of housings on the second half of the cycle, with the pairs of housings exchanging roles cyclically. The prior art does not fairly show or teach a metering pump rod that moves on a threaded screw wherein the screw penetrates the piston to achieve compact size.

A primary objective of the present invention is to provide an apparatus and method of use of such apparatus that provides advantages not taught by the prior art.

Another objective is to provide such an invention capable of metering flow of a semi-fluid.

A further objective is to provide such an invention capable of metering an essentially continuous flow of the semi-fluid.

A still further objective is to provide such an invention capable of metering continuous flow of plural components of a compound and joining the components in a mixing stream.

A still further objective is to provide such an invention in a highly compact size and in a simple arrangement of components.

Other features and advantages of the present invention will become apparent from the following more detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate the present invention. In such drawings:

Figure 1 is a schematic elevational front view of the preferred embodiment of the invention shown in section with push-pull interactive metering action;

Figure 1A is a schematic of a switch portion of Fig. 1 showing an alternate position of a rotating conduit member thereof; and

Figure 2 is a front elevational perspective view thereof defining the structure and method of continuous metering of plural components of a mixture.

DETAILED DESCRIPTION OF THE INVENTION

The above described drawing figures illustrate the invention in at least one of its preferred embodiments, which is further defined in detail in the following description.

The present invention is a metering pumping apparatus and method of metering of fluids, and particularly for semi-fluids or highly viscous fluids such as epoxy, waxes, tars and pastes, referred to herein simply as "fluid" or "fluids" (not shown). It can be appreciated that the fluids metered with the present invention may be any fluid whatsoever and is not limited to those listed or referred to herein. The present fluid metering apparatus comprises one or more, i.e., plural pairs, of metering units, each having a cylindrical housing 10 and all of which are essentially identical in construction and function. It can be appreciated that a single pair of the metering units, as shown in Fig. 1, are used for dispensing a single fluid, while plural pairs of the units, as shown in Fig. 2, will be advantageously used for dispensing mixtures of two or more fluids. Each of the housings 10 provides a single fluid exchange port 14 which enabled the fluid to move into and out of the housing 10 as will be further described below. Now, with respect to each of the housings 10, a screw 20 is aligned longitudinally with the housing 10, while a means for rotating 30 is engaged with the screw 20 for rotating the screw 20 alternately in clockwise and counter-clockwise senses. It will be appreciated that the rotating means 30 shown in Figs. 1 and 2 enables the two screws 20 to always rotate in opposing senses. In the figures, it will be appreciated that a gear or sprocket is shown, but that any means for rotation known in the art may be employed and will be operated according to this specification. For instance, a direct drive using electric or hydraulic motors may be employed and connected directly to screws 20. In any drive means employed in this invention, the screws 20 must turn in opposing senses at all times.

In each unit, A rod 40 provides a fixedly fastened nut 42 at one end of the rod 40, and the nut 42 is thrededly engaged with the screw 20, the screw 20 penetrating into a hollow space 44 within the rod 40. It will be appreciated that nut 42 may be a plate with a threaded hole 43 for accepting the screw 20. The rod 40 linearly translates along the screw 20 in response to rotation of the screw 20 and this is clearly shown in Fig. 1 which shows the rods 40 at lower and upper extreme positions on screws 20. The port 14 is positioned at a distal end 12 of the housing 10, preferably below the rod 40 as shown in Fig. 1, wherein, translation of the rod 40 toward and away from the port 14 draws the fluid into and expels the fluid out of the

housing 10 respectively. This occurs because the rod 40 is sealed by sliding seal 16 in a manner well known in the art, i.e., by o-rings, chevrons seals, etc. A means for physically supporting 5 the screws 20 and rotating means 30, shown in the figures prevents screws 20 from moving other than rotating, and such supporting means 5 may be any well known mounting structure.

The means for rotating 30 is enabled for rotating the screws 20 of each of the pairs of the housings 10 in opposing directions at any one instant, such that the fluid is expelled from one of the housings 10 of each of the pairs of housings, while the other of the housings 10 of each of the pairs of housings draws the fluid in, the drawing and expelling taking place in an alternating, push-pull cycle within each of the pairs of the housings 10. It will be appreciated that the purpose of the pair of metering devices that comprise the present invention, operate to provide a continuous flow of a single fluid and how this occurs will be described below.

A means for fluid conduction 60, 70 and 70' is comprised of a series of tubes or similar fluid passages, as shown in Fig. 1, and includes a double-throw fluid switch 60, a commercially available rotating switch. In this switch 60 a rotating portion provides dual passages P1 and P2 which may be aligned with tubes 70 and 70' in alternate arrangements. The rotating portion may be positioned as shown in Fig. 1 where passage P1 is aligned for conducting fluid from the port 14 on the left, to discharge tube 70', and passage P2 is aligned for conducting fluid from supply container 80 to port 14 on the right. As shown by the arrows, the flows occur simultaneously. The alternate position of the rotating portion of switch 60 is shown in Fig. 1A where, with a rotation of 90 degrees in the clockwise direction of switch 60, passage P1 is aligned for conducting fluid from supply container 80 to port 14 on the left, and passage P2 is aligned for conducting fluid from port 14 on the right to discharge tube 70', again, simultaneously. In summary then, switch 60 is enabled for directing the fluid to one of the housings 10 and simultaneously directing fluid from the other of the housings 10 when the switch 60 is in a first position of the fluid switch. The switch 60

further simultaneously enables directing fluid to the other of the housings and directing fluid from the one of the housings when placed in its second position. Switch 60 is able to move between its two operating positions in milliseconds by rotating 90 degrees CW and then 90 CCW alternately, or by simply rotating in 90 degree increments sequentially in one rotation sense whereby passages P1 and P2 exchange roles after each two 90 degree movements. Either mode of operation of switch 60 will achieve a similar result. The rods 40 are able to reverse their directions nearly as fast as the 90 degree rotation of switch 60 so that the fluid that is exiting switch 60 via conduit 70', for all practical purposes, moves with continuous flow.

As shown in Fig. 2, the fluid conduction means 60, 70, 70' and 70" enables mixing of the fluids from at least two of the plural pairs of cylindrical housings 10 and dispensing the mixture from tube 70". One important application of this process is the dispensing of two-part epoxy resins and other mixtures requiring a catalyst or hardener. Other plural component mixes may be similarly dispensed and such may have more than two components.

Clearly the rate of flow R1 of the fluids from the switch 60 on the left in Fig. 2 may be different from the rate of flow R2 from the switch 60 on the right. In this manner, the preparation of two or more component mixtures with unequal component amounts may be precisely controlled and continuously dispensed. Adapting rate of flow from each pair of units is addressed below.

As defined above, the fluid metering method of the present invention comprising the steps of providing the distal fluid exchange port 14 in each of the at least one pair of cylindrical housings 10, aligning the screws 20 longitudinally with the housings 10, engaging the means for rotating 30 with the screws 20, rotating the screws 20 alternately in clockwise and counter-clockwise senses, engaging the nuts 42 on one end of the rods 40 with the screws 20 so that they are able to penetrate within the hollow spaces 44 within the rods 40, drawing

and expelling the fluid through the ports 14 by linear translating of the rods 40 along the screws 20 in response to their rotation by the rotating means 30, positioning the fluid conduction means 60, 70 and 70' relative to at least one of the plural pairs of housing 10, in a first state or position, wherein the fluid is directed away from one of the housings 10 and toward another of the housings 10 in one-half of a metering cycle of the method, and in a second state or position of the conduction means 60, 70 and 70' directing the fluid toward the one of the housings 10 and away from the another of the housings 10 in a second-half of the metering cycle of the method. Clearly, the pitch of the teeth shown on the planar gears of the rotating means 30 and the pitch of the threads shown on the screws 20 defines the resolution of the present metering method, i.e., the smallest theoretical volume of the fluid that may be dispensed from tube 70'. The rate of flow of the fluid from each of the switches 60 is dependent upon the rotational rate of rotating means 30 and the screw lead of screws 20, i.e., the ratio of linear advance of rod 40 for each rotation. The total volume of the housing 10 defines the maximum output per half cycle that the system is capable of dispensing. The volume of supply container 80 defines the total output capacity of the system before reloading of the supply container 80 is required. At tube 70" a mixture of plural fluid components is dispensed.

In an alternate embodiment of the present invention, when the rod 40 is too small in diameter to accept a screw 20, the screw may be mounted to one side of the rod 40, with the nut 42 laterally extensive in engaging the screw, so that the rod 40 moves in parallel to the screw 20 which, as defined above, rotates but does not translate. All translation is confined to the rod 40, as above. This embodiment is described here but not shown in the figures and not claimed. This alternative embodiment provides the benefits of the primary embodiment defined in this application above, in that the screw 20 and rod 40 are related in such a manner as to provide a more compact machine since the rod 40 overlaps the screw 20 in its motion within housing 10. In the above earlier described embodiment by driving the rod 40 up and over screw 20, and in this later described embodiment by driving the rod 40 along side the screw 20.

While the invention has been described with reference to at least one preferred embodiment, it is to be clearly understood by those skilled in the art that the invention is not limited thereto. Rather, the scope of the invention is to be interpreted only in conjunction with the appended claims and it is made clear, here, that the inventor(s) believe that the claimed subject matter is the invention.